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FOR

A FREQUENCY-DIVISION MARKER FOR AN ELECTRONIC ARTICLE SURVEILLANCE SYSTEM

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A FREQUENCY-DIVISION MARKER FOR AN ELECTRONIC ARTICLE SURVEILLANCE SYSTEM

BACKGROUND

An Electronic Article Surveillance (EAS) system is designed to prevent unauthorized removal of an item from a controlled area. A typical EAS system may comprise a monitoring system and one or more security tags. The monitoring system may create an interrogation zone at an access point for the controlled area. A security tag may be fastened to an item, such as an article of clothing. If the tagged item enters the interrogation zone, an alarm may be triggered indicating unauthorized removal of the tagged item from the controlled area.

EAS systems typically use radio frequency (RF) spectrum to convey signals between the monitoring system and security tags. Certain EAS systems, however, may have a limited amount of RF spectrum available to convey such signals. Consequently, there may be need for improvements in EAS systems to take advantage of the available RF spectrum.

BRIEF DESCRIPTION OF THE DRAWINGS

The subject matter regarded as the embodiments is particularly pointed out and distinctly claimed in the concluding portion of the specification. The embodiments, however, both as to organization and method of operation, together with objects, features, and advantages thereof, may best be understood by reference to the following detailed description when read with the accompanying drawings in which:

FIG. 1 illustrates an EAS system suitable for practicing one embodiment;

FIG. 2 illustrates a block diagram of a marker in accordance with one embodiment;

FIG. 3 is a block flow diagram of the operations performed by a marker in accordance with one embodiment;

FIG. 4 is a first circuit for implementing a marker in accordance with one embodiment; and

FIG. 5 is a second circuit for implementing a marker in accordance with one embodiment.

DETAILED DESCRIPTION

The embodiments may be directed to an EAS system in general. More particularly, the embodiments may be directed to a marker for an EAS security tag. The marker may comprise, for example, a frequency-division marker configured to receive input RF energy. The frequency-division marker may recondition the received RF energy, and emit an output signal with a frequency that is less than the input RF energy. In one embodiment, for example, the output signal may have half the frequency of the input RF energy. This type of frequency-division marker may be suitable for use in low bandwidth environments, such as the 13.56 Megahertz (MHz) Industrial, Scientific and Medical (ISM) band.

Conventional EAS systems are unable to effectively operate in the 13.56 MHz ISM band. Conventional EAS systems typically use a marker consisting of a single inductor-capacitor (LC) combination resonant circuit configured to resonate at a predetermined frequency. Due to the high operating frequency of the 13.56 MHz ISM band, such a marker may require an inductor with a few turns, and a capacitor ranging between 10-100 picofarads (pF). Detecting such a single-resonance marker, however, may require a relatively complicated detection system, such as "swept RF" or "pulse" detection systems. A swept RF detection system may be capable of generating signal and receiving reflected signal at a relatively wide frequency range. A pulse detection system may create a burst of energy at a specific frequency to energize the marker, and then detects the marker's ringdown waveform. In either case, the detection system requires generating energy at a relatively wide spectrum which is not suitable for use with a 13.56 MHz system.

An EAS system using a frequency-division marker configured to operate in the 13.56 MHz ISM band may offer several advantages compared to conventional EAS

systems. For example, the 13.56 MHz ISM band permits relatively high amounts of transmitting power, which may increase the detection range for an EAS system. In another example, an improved detector may be configured to perform continuous detection, and may use sophisticated signal processing techniques to improve detection range. In yet another example, the relatively high operating frequency may allow the marker to have a relatively flat geometry as well as reduce degradation under restriction, thereby making it easier to apply the marker to a monitored item.

Numerous specific details may be set forth herein to provide a thorough understanding of the embodiments of the invention. It will be understood by those skilled in the art, however, that the embodiments of the invention may be practiced without these specific details. In other instances, well-known methods, procedures, components and circuits have not been described in detail so as not to obscure the embodiments of the invention. It can be appreciated that the specific structural and functional details disclosed herein may be representative and do not necessarily limit the scope of the invention.

It is worthy to note that any reference in the specification to "one embodiment" or "an embodiment" means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment. The appearances of the phrase "in one embodiment" in various places in the specification are not necessarily all referring to the same embodiment.

Referring now in detail to the drawings wherein like parts are designated by like reference numerals throughout, there is illustrated in FIG. 1 an EAS system suitable for practicing one embodiment. FIG. 1 is a block diagram of an EAS system 100. In one embodiment, for example, EAS system 100 may comprise an EAS system configured to operate using the 13.56 MHz ISM band. EAS system 100, however, may also be configured to operate using other portions of the RF spectrum as desired for a given implementation. The embodiments are not limited in this context.

As shown in FIG. 1, EAS system 100 may comprise a plurality of nodes. The term "node" as used herein may refer to a system, element, module, component, board or device that may process a signal representing information. The signal may be, for

example, an electrical signal, optical signal, acoustical signal, chemical signal, and so forth. The embodiments are not limited in this context.

As shown in FIG. 1, EAS system 100 may comprise a transmitter 102, a security tag 106, a detector 112 and an alarm system 114. Security tag 106 may further comprise a marker 108. Although FIG. 1 shows a limited number of nodes, it can be appreciated that any number of nodes may be used in EAS system 100. The embodiments are not limited in this context.

In one embodiment, EAS system 100 may comprise a transmitter 102. Transmitter 102 may be configured to transmit one or more interrogation signals 104 into an interrogation zone 116. Interrogation zone 116 may comprise an area between a set of antenna pedestals set at the entrance/exit point for a controlled area, for example. Interrogation signals 104 may comprise electromagnetic radiation signals having a first predetermined frequency. In one embodiment, for example, the predetermined frequency may comprise 13.56 MHz. Interrogation signals 110 may trigger a response from a security tag, such as security tag 106.

In one embodiment, EAS system 100 may comprise a security tag 106. Security tag 106 may be designed to attach to an item to be monitored. Examples of tagged items may include an article of clothing, a Digital Video Disc (DVD) or Compact Disc (CD) jewel case, a movie rental container, packaging material, and so forth. Security tag 106 may comprise marker 108 encased within a security tag housing. The security tag housing may be hard or soft, depending on the item to which security tag 106 is to be attached. Housing selection may also vary depending upon whether security tag 106 is designed to be a disposable or reusable tag. For example, a reusable security tag typically has a hard security tag housing to endure the rigors of repeated attaching and detaching operations. A disposable security tag may have a hard or soft housing, depending on such as factors as cost, size, type of tagged item, visual aesthetics, tagging location (e.g., source tagging and retail tagging), and so forth. The embodiments are not limited in this context.

In one embodiment, security tag 106 may comprise a marker 108. Marker 108 may comprise a frequency-division device having an RF antenna to receive interrogation signals, such as interrogation signals 104 from transmitter 102, for example. Marker 108

may also comprise a RF sensor to emit one or more marker signals 110 in response to interrogation signals 104. Marker signals 110 may comprise electromagnetic radiation signals having a second predetermined frequency that is different from the first predetermined frequency of interrogation signals 104. In one embodiment, for example, the first predetermined frequency may comprise 13.56 MHz and the second predetermined frequency may comprise half of 13.56 MHz, or 6.78 MHz. Marker 108 may be discussed in more detail with reference to FIGS. 2-5.

In one embodiment, EAS system 100 may comprise detector 112. Detector 112 may operate to detect the presence of security tag 106 within interrogation zone 116. For example, detector 112 may detect one or more marker signals 110 from marker 108 of security tag 106. The presence of marker signals 110 indicate that an active security tag 106 is present in interrogation zone 116. In one embodiment, detector 112 may be configured to detect electromagnetic radiation having the second predetermined frequency of 6.78 MHz, which is half the first predetermined frequency of 13.56 MHz generated by transmitter 102. Detector 112 may generate a detection signal in accordance with the detection of security tag 106.

It is worthy to note that since the marker signal is in a different frequency from the interrogation signal, a single frequency system can be employed to detect the marker signal. Detector 112 may detect the marker signal as long as its front-end circuitry is not saturated by the incoming fundamental signal of 13.56 MHz. The use of a single frequency system may increase digital signal processor (DSP) processing time to achieve better detection performance.

In one embodiment, EAS system 100 may comprise an alarm system 114. Alarm system 114 may comprise any type of alarm system to provide an alarm in response to a detection signal. The detection signal may be received from detector 112, for example. Alarm system 114 may comprise a user interface to program conditions or rules for triggering an alarm. Examples of the alarm may comprise an audible alarm such as a siren or bell, a visual alarm such as flashing lights, or a silent alarm. A silent alarm may comprise, for example, an inaudible alarm such as a message to a monitoring system for a security company. The message may be sent via a computer network, a telephone

network, a paging network, and so forth. The embodiments are not limited in this context.

In general operation, EAS system 100 may perform anti-theft operations for a controlled area. For example, transmitter 102 may send interrogation signals 104 into interrogation zone 116. When security tag 106 is within the interrogation zone, marker 108 may receive interrogation signals 104. Marker 108 may generate marker signals 110 in response to interrogation signals 104. Marker signals 110 may have approximately half the frequency of interrogation signals 104. Detector 112 may detect marker signals 110, and generate a detection signal. Alarm system 114 may receive the detection signal, and generate an alarm signal to trigger an alarm in response to the detection signal.

FIG. 2 may illustrate a marker in accordance with one embodiment. FIG. 2 may illustrate a marker 200. Marker 200 may be representative of, for example, marker 108. Marker 200 may comprise one or more modules. Although the embodiment has been described in terms of "modules" to facilitate description, one or more circuits, components, registers, processors, software subroutines, or any combination thereof could be substituted for one, several, or all of the modules. The embodiments are not limited in this context.

As shown in FIG. 2, marker 200 may comprise a dual resonance device. More particularly, marker 200 may comprise a first resonant circuit 202 connected to a second resonant circuit 204. Although FIG. 2 shows a limited number of modules, it can be appreciated that any number of modules may be used in marker 200.

In one embodiment, marker 200 may comprise first resonant circuit 202. First resonant circuit 202 may be a resonance LC circuit configured to receive interrogation signals 104. First resonant circuit 202 may be resonant at a first frequency F for receiving electromagnetic radiation at the first frequency F. For example, first resonant circuit 202 may generate a first resonant signal having a first resonant frequency in response to interrogation signals 110. The first resonant frequency may comprise, for example, approximately 13.56 MHz.

In one embodiment, marker 200 may comprise second resonant circuit 204. Second resonant circuit 204 may also be a resonance LC circuit configured to receive the first resonant signal from resonant circuit 202. Second resonant circuit 202 may be

resonant at a second frequency *F/2* that is one-half the first frequency *F* for transmitting electromagnetic radiation at the second frequency *F/2*. For example, second resonant circuit 204 may generate a second resonant signal having a second resonant frequency in response to the first resonant signal. The second resonant frequency may comprise, for example, approximately 6.78 MHz.

In one embodiment, first resonant circuit 202 and second resonant circuit 204 may be positioned relative to each other such that both circuits are magnetically coupled. The magnetic coupling may allow first resonant circuit 202 to transfer energy to second resonant circuit 204 at the first frequency *F* in response to receipt by first resonant circuit 202 of electromagnetic radiation at the first frequency *F*. Second resonant circuit 204 may be configured with a voltage dependant variable capacitor in which the reactance varies with variations in energy transferred from first resonant circuit 202. This variation may cause second resonant circuit 204 to transmit electromagnetic radiation at the second frequency *F/2* in response to the energy transferred from first resonant circuit 202 at the first frequency *F*.

FIG. 3 illustrates operations for a marker in accordance with one embodiment. Although FIG. 3 as presented herein may include a particular set of operations, it can be appreciated that the operations merely provide an example of how the general functionality described herein can be implemented. Further, the given operations do not necessarily have to be executed in the order presented unless otherwise indicated. The embodiments are not limited in this context.

FIG. 3 illustrates a flow of operations 300 for a marker that may be representative of the operations executed by marker 200 in accordance with one embodiment. As shown in flow 300, an interrogation signal may be received at a first resonant circuit for a marker at block 302. A first resonant signal having a first resonant frequency may be generated in response to the interrogation signal at block 304. The first resonant signal may be received at a second resonant circuit overlapping the first resonant circuit at block 306. A second resonant signal having a second resonant frequency may be generated in response to the first resonant signal, with the second resonant frequency being different from the first resonant frequency, at block 308. For example, the second resonant frequency may be approximately half of the first resonant frequency.

FIG. 4 is a first circuit for implementing a marker in accordance with one embodiment. FIG. 4 illustrates a circuit 400. Circuit 400 may comprise a dual resonance configuration for marker 200. In one embodiment, circuit 400 may comprise a first resonant circuit 402 and a second resonant circuit 404.

In one embodiment, circuit 400 may comprise one or more planarized coils. The term "planarized coil" as used herein may refer to a coil having a relatively flat geometry. For example, the planarized coil may be less than 1 millimeter (mm) thick. In another example, the planarized coil may be approximately .2 mm or 200 microns thick. The thickness of any given planarized coil may vary according to a given implementation, and the embodiments are not limited in this context.

In one embodiment, circuit 400 may comprise first resonant circuit 402. First resonant circuit 402 may comprise an inductor-linear capacitor combination. For example, first resonant circuit 402 may comprise a first planarized coil 406 having a pair of terminals and a capacitor C1 connected to the pair of terminals. Capacitor C1 may comprise a linear or non-linear capacitor depending on a given implementation. In one embodiment, for example, capacitor C1 may comprise a linear capacitor. First resonant circuit 402 may be resonant at a first predetermined frequency when receiving electromagnetic radiation at the first predetermined frequency. The number of turns for first planarized coil 406 may vary depending on the frequency of interrogation signals 104. With an operating frequency of 13.56 MHz, first planarized coil 406 may have approximately 10 turns, which may be sufficient for resonance and transmitter coupling needed to induce the appropriate operating voltage. As it receives the electromagnetic energy from transmitter 102, first resonant circuit stores and amplifies the field. The field may be passed to second resonant circuit 404 through the magnetic coupling discussed below.

In one embodiment, circuit 400 may comprise second resonant circuit 404. Second resonant circuit 404 may comprise an inductor-nonlinear capacitor combination. For example, second resonant circuit 404 may comprise a second planarized coil 408 having a pair of terminals and a non-linear capacitor D1 connected to the pair of terminals. Non-linear capacitor D1 may operate as a voltage dependent variable capacitor. Second resonant circuit 404 may receive the amplified field from first resonant

circuit 402, and generates a second resonant signal at a second resonant frequency that is half the frequency of the interrogation signal and first resonant signal. In one embodiment, second resonant circuit 404 may generate the second resonant signal at 6.78 MHz with a magnetic field threshold of approximately 10 mA/m rms.

One advantage of circuit 400 is that it may have a lower magnetic field threshold as compared to conventional frequency-division circuits. The frequency-division process has a minimum threshold below which it will not operate. Therefore, the transmitting field at the marker must exceed a minimum magnetic field threshold. The lower the threshold, the more sensitive the marker becomes. Conventional frequency-division markers using an inductor-zener diode combination may have a typical turn-on threshold of approximately 100 mA/m rms. In one embodiment, circuit 400 may output a marker signal at 6.78 MHz with a magnetic field threshold of approximately 10 mA/m rms. As a result, marker 200 using circuit 400 may result in a more sensitive marker for improved EAS functionality.

As shown in FIG. 4, first planarized coil 406 and second planarized coil 408 are positioned so that they overlap each other by a predetermined amount to form a double tuned circuit. The amount of overlap determines the degree of mutual coupling k between the magnetic fields of each resonant circuit. To perform frequency division, the coupling coefficient k between first planarized coil 406 of first resonant circuit 402 and second planarized coil 408 of second resonant circuit 404 should be within a range of 0.0 to 0.6. In one embodiment, for example, k may comprise 0.3 to perform sufficient coupling between the fields.

Second resonant circuit 404 may utilize a number of different non-linear capacitors for D1. For example, the non-linear capacitor D1 may be implemented using a zener diode, a varactor, a metal-oxide semiconductor (MOS) capacitor, and so forth. The particular non-linear capacitor element may be determined in accordance with a number of different factors. For example, one factor may be capacitance non-linearity (dC/dV). The turn on magnetic field threshold may depend on the dC/dV value at zero voltage bias condition. The higher the dC/dV value, the lower the threshold. In another example, one factor may be capacitive dissipation (Df). The dissipation factor determines the amount of energy a resonant LC circuit can store. The lower the Df, the more efficient the circuit

may operate. Other factors such as inductor-capacitor ratio and coil loss may also influence the frequency-dividing functionality.

An MOS capacitor can also be used as a non-linear element. An MOS capacitor may offer superior dC/dV characteristics. This may improve device sensitivity significantly. In addition, proximity deactivation can be achieved through the breakdown mechanism of the MOS device. The MOS breakdown voltage can be controlled by adjusting the thickness of the oxide layers. To deactivate, a F/2 frequency may be generated and resonated in the inductor-nonlinear capacitor resonator until the MOS breakdown voltage is reached.

FIG. 5 is a second circuit for implementing a marker in accordance with one embodiment. FIG. 5 illustrates a circuit 500. Circuit 500 may comprise a different dual resonance configuration for marker 200. In one embodiment, circuit 500 may comprise a first resonant circuit 502 and a second resonant circuit 504. First resonant circuit 502 and second resonant circuit 504 may be similar to first resonant circuit 402 and second resonant circuit 404, respectively. First resonant circuit 502 may comprise a first planarized coil 506 and a linear capacitor C1. Second resonant circuit 504 may comprise a second planarized coil 508 and a non-linear capacitor D1.

In one embodiment, circuit 500 comprises a coil arrangement to achieve a coupling of 0.3. Circuit 500 may illustrate a dual-resonance configuration having one LC resonant circuit within another LC resonant circuit. As shown in circuit 500, second resonant circuit 504 may be nested within first planarized coil 506 of first resonant circuit 502. By placing the *F* resonant circuit outside the *F/2* resonant circuit, this configuration may provide improved sensitivity by increasing the field capture area. Although circuit 500 shows second resonant circuit 504 being nested within first planarized coil 506, it may be appreciated that the reverse configuration may be implemented and still fall within the scope of the embodiments. The embodiments are not limited in this context.

Frequency division markers such as circuits 400 and 500 may be manufactured in a number of different ways. For example, the inductor metal pattern can be deposited, etched, stamped, or otherwise placed on a thin and flexible substrate. The non-linear capacitor may be bonded to the inductor terminals. Conventional bonding techniques may result in a marker having a slight bump due to the placement of the nonlinear

capacitor element. To avoid this bump, an organic semiconductor process may be used. The organic semiconductor process can fabricate conductor patterns and the nonlinear capacitor element in a single, flexible substrate in a mass-production scale. The embodiments are not limited in this context.

Although the embodiments have been discussed in terms of dual-resonance configurations, it may be appreciated that a single LC resonant circuit may also be implemented using the principles discussed herein. For example, a single LC resonant circuit comprising a non-linear capacitor and planarized coil may be configured to operate in the 13.56 MHz band. The higher operating frequencies may result in reduced geometries and smaller form factors for the single LC resonant circuit, while still emitting a detectable resonant signal at the appropriate frequency. The embodiments are not limited in this context.

One or more embodiments, or portions of embodiments, may be implemented using an architecture that may vary in accordance with any number of factors, such as desired computational rate, power levels, heat tolerances, processing cycle budget, input data rates, output data rates, memory resources, data bus speeds and other performance constraints. For example, one portion of an embodiment may be implemented using software executed by a processor. The processor may be a general-purpose or dedicated processor, such as a processor made by Intel® Corporation, for example. The software may comprise computer program code segments, programming logic, instructions or data. The software may be stored on a medium accessible by a machine, computer or other processing system. Examples of acceptable mediums may include computer-readable mediums such as read-only memory (ROM), random-access memory (RAM), Programmable ROM (PROM), Erasable PROM (EPROM), magnetic disk, optical disk, and so forth. In one embodiment, the medium may store programming instructions in a compressed and/or encrypted format, as well as instructions that may have to be compiled or installed by an installer before being executed by the processor. In another example, a portion of one embodiment may be implemented as dedicated hardware, such as an Application Specific Integrated Circuit (ASIC), Programmable Logic Device (PLD) or DSP and accompanying hardware structures. In yet another example, a portion of one embodiment may be implemented by any combination of programmed general-purpose

computer components and custom hardware components. The embodiments are not limited in this context.

While certain features of the embodiments of the invention have been illustrated as described herein, many modifications, substitutions, changes and equivalents will now occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the embodiments of the invention.